DOCUMENT RESUME

ED 309 060 SE 050 713

TITLE	Science for All Americans: Summary, Project 2061.
INSTITUTION	American Association for the Advancement of Science, Washington, D.C.
SPONS AGENCY	Andrew W. Mellon Foundation, New York, N.Y.; Carnegie Corp. of New York, N.Y.
PUB DATE	89
NOTE	17p.; For other Project 2061 panel reports, see SE 050 707-711. For overview, see SE 050 712.
AVAILABLE FROM	AAAS Books, Dept. 2061, P.O. Box 753, Waldorf, MD 20604 (for price, contact AAAS offices; quantity prices available).
PUB TYPE	Reports - Descriptive (141) -- Viewpoints (120)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Educational Change; Educational Improvement; Elementary Secondary Education; Futures (of Society); *Mathematics Education; Science and Society; *Science Curriculum; *Science Education; Scientific Attitudes; *Scientific Enterprise; Scientific Principles; Technology
IDENTIFIERS	*Project 2061 (AAAS); *Science Policy

ABSTRACT

Project 2061 is a three-phase plan of action designed to contribute to the reform of science, mathematics, and technology education. Phase I was to establish a conceptual base for reform by spelling out the knowledge, skills, and attitudes that all students should acquire as a result of their experiences from kindergarten through high school. Phase II was to design alternative curriculum models to promote scientific literacy in the schools. Phase III was to implement the recommendations of this project. This pamphlet was designed to summarize Project 2061 and was intended to serve as an introduction to Project 2061. It includes discussions of the recommendations of the project, including the dimensions of scientific literacy, details of what students should understand about the nature of science, details of scientific ways of knowing, science perspectives, and the qualities of a scientific attitude; and describes necessary actions in the second and third phases of the project. A list of the members of the National Council on Science and Technology Education and the Project 2061 Staff is included. (CW)

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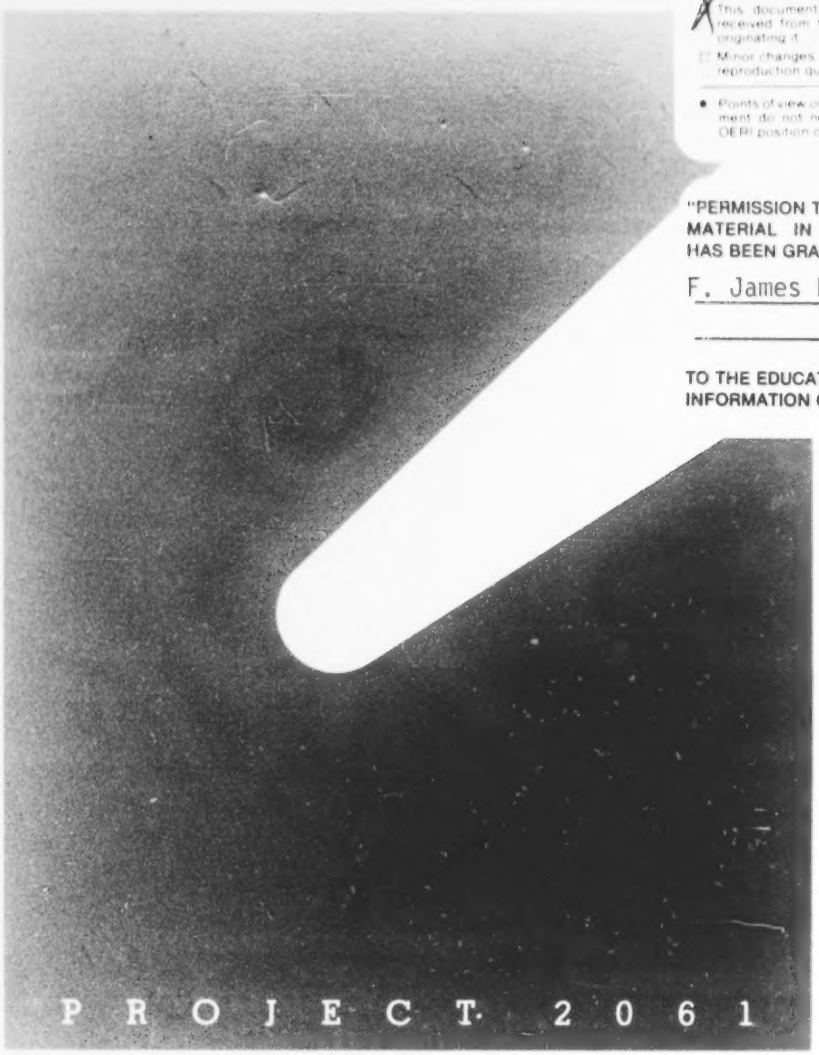

SCIENCE FOR ALL AMERICANS

SUMMARY

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SE 050 173

SCIENCE FOR ALL AMERICANS

SUMMARY

PROJECT 2061

AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE
1989

Founded in 1848, the American Association for the Advancement of Science is the world's leading general scientific society, with more than 132,000 individual members and nearly 300 affiliated scientific and engineering societies and academies of science. The AAAS engages in a variety of activities to advance science and human progress. To help meet these goals, the AAAS has a diversified agenda of programs bearing on science and technology policy; the responsibilities and human rights of scientists; intergovernmental relations in science; the public's understanding of science; science education; international cooperation in science and engineering; and opportunities in science and engineering for women, minorities, and the disabled. The AAAS also publishes *Science*, a weekly journal for professionals, and *Science Books & Films*, a review magazine for schools and libraries.

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Printed in the United States of America

PREFACE

Scientific literacy is a national goal. But what is the substance of such literacy? Who should be expected to acquire the requisite knowledge and skills? And how can scientific literacy be achieved nationwide?

Developing answers to these questions is the central purpose of Project 2061, a far-reaching enterprise launched by the American Association the Advancement of Science to help bring about the reform of education in science, mathematics, and technology.

The first phase of this project has established a conceptual base for such reform by identifying the knowledge, skills, and habits of mind that all students should have acquired by the time they finish high school. This base consists of recommendations presented in separate reports. Five of these are reports of the work done by independent scientific panels devoted to specific subjects. The sixth one, *Science for All Americans,* cuts across all of science, mathematics, and technology.

This summary of *Science for All Americans* is designed to serve as an introduction to Project 2061. Our hope is that it will enable educators, policymakers, scientists, and others to become aware of the purpose of the project and the scope of the recommendations—developed by the National Council on Science and Technology Education—concerning scientific literacy.

I would like to emphasize that this brief document is not a substitute for the report itself. Accordingly, I encourage anyone with an interest in educational reform to closely examine the recommendations as set forth in the full report and also to read the individual panel reports.

F. James Rutherford
Project Director, Project 2061

SUMMARY

Science for All Americans is about scientific literacy. The core of the report consists of a set of recommendations by the National Council on Science and Technology Education—a distinguished group of scientists and educators appointed by the American Association for the Advancement of Science—on what understandings and habits of mind are essential for all citizens in a scientifically literate society.

Scientific literacy—which embraces science, mathematics, and technology—has emerged as a central goal of education. Yet the fact is that general scientific literacy eludes us in the United States. A cascade of recent studies has made it abundantly clear that by both national standards and world norms, U.S. education is failing too many students—and hence failing the nation. By all accounts, America has no more urgent priority than the reform of education in science, mathematics, and technology.

Reform is needed because the nation has not yet acted decisively enough in preparing young people, especially the minority children on whom the nation's future is coming to depend, for a world that continues to change radically in response to the rapid growth of scientific knowledge and technological power. But educational reform cannot simply be legislated. It will take time, determination, collaboration, resources, and leadership. It will take daring and experimentation. And it will take a shared national vision of what Americans want their schools to achieve. *Science for All Americans*—part of a AAAS initiative called Project 2061—is intended to help in the formulation of that vision.

In preparing its recommendations, the national council drew on the reports of five independent scientific panels. In addition, the national council sought the advice of a large and diverse array of consultants and reviewers—scientists, engineers, mathematicians, historians, and educators. In all, the process took more than three years, involved hundreds of individuals, and culminated in the unanimous approval of *Science for All Americans* by the board of directors of the AAAS.[1]

PROJECT 2061 AND SCIENTIFIC LITERACY

Science for All Americans, the first report of Project 2061, has little to say about what ails the educational system, points no finger of blame, prescribes no specific remedies. Rather, its basic purpose is to characterize scientific literacy. Thus, its recommendations are presented in the form of basic learning goals for all American children. A fundamental premise of Project 2061 is that the schools do not need to be asked to teach more and more, but to teach less so that it can be taught better. Accordingly, the recommendations given in *Science for*

[1] The AAAS gratefully acknowledges the generous financial support provided by the Carnegie Corporation of New York and the Andrew W. Mellon Foundation, without which the Phase I effort would not have been possible.

All Americans for a common core of learning are limited to the ideas and skills that have the greatest scientific and educational significance.

The AAAS initiated Project 2061 in 1985, a year when Comet Halley happened to be in the earth's vicinity. That coincidence prompted the project's name, for it was realized that the children who would live to see the return of the comet in 2061, a human lifetime from now, would soon be starting their school years.

Project 2061 has a three-phase plan of purposeful and sustained action that will contribute to the critically needed reform of education in science, mathematics, and technology.

Phase I focused on the substance of scientific literacy. *Science for All Americans* and the reports of the scientific panels constitute the chief products of that phase. The purpose of Phase I was to establish a conceptual base for reform by spelling out the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience from kindergarten through high school.

Phase II involves teams of educators and scientists transforming *Science for All Americans* into several alternative curriculum models for the use of school districts and states. During this phase, the project is also drawing up blueprints for reform related to the education of teachers, materials and technologies for teaching, testing, the organization of schooling, educational policies, and educational research. While engaged in creating these new resources, Project 2061 is trying to significantly enlarge the nation's pool of experts in school science curriculum reform and is continuing its effort to publicize the need for nationwide scientific literacy.

Phase III will be a widespread collaborative effort, lasting a decade or longer, in which many groups active in educational reform will use the resources of Phases I and II to move the nation toward scientific literacy. Strategies for implementing the reform of education in science, mathematics, and technology in the nation's schools will be developed by those who have a stake in the effectiveness of the schools and who will take into account the history, economics, and politics of change.

RECOMMENDATIONS

The national council's recommendations address the basic dimensions of scientific literacy, which, in the most general terms, are:

- Being familiar with the natural world and recognizing both its diversity and its unity
- Understanding key concepts and principles of science
- Being aware of some of the important ways in which science, mathematics, and technology depend upon one another
- Knowing that science, mathematics, and technology are human enterprises and knowing what that implies about their strengths and limitations
- Having a capacity for scientific ways of thinking
- Using scientific knowledge and ways of thinking for individual and social purposes

The council's recommendations cover a broad array of topics. Many of these topics are already common in school curricula (for example, the structure of matter, the basic functions of cells, prevention of disease, communications technology, and different uses of numbers). However, the treatment of such topics tends to differ from the traditional in two ways.

One difference is that boundaries between traditional subject-matter categories are softened and connections are emphasized. Transformations of energy, for example, occur in physical, biological, and technological systems, and evolutionary change appears in stars, organisms, and societies.

A second difference is that the amount of detail that students are expected to retain is considerably less than in traditional science, mathematics, and technology courses. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures. The sets of ideas that are chosen not only make some satisfying sense at a simple level but also provide a lasting foundation for learning more. Details are treated as a means of enhancing, not guaranteeing, students' understanding of a general idea. The council believes, for example, that basic scientific literacy implies knowing that the chief function of living cells is assembling protein molecules according to instructions coded in DNA molecules, but that it does not imply knowing such terms as "ribosome" or "deoxyribonucleic acid."

The national council's recommendations include some topics that are not common in school curricula. Among those topics are the nature of the scientific enterprise, and how science, mathematics, and technology relate to one another and to the social system in general. The council also calls for some knowledge of the most important episodes in the history of science and technology, and of the major conceptual themes that run through almost all scientific thinking.

The council's recommendations, which in the report are presented in 12 chapters, can be summarized in four general categories: The Scientific Endeavor, Scientific Views of the World, Perspectives on Science, and Scientific Habits of Mind.

The Scientific Endeavor

All students should leave school with an awareness of what the scientific endeavor is and how it relates to their culture and their lives. This awareness should include understanding the following:

- The scientific endeavor stems from the union of science, mathematics, and technology. Technology provides science and mathematics with tools and techniques that are essential for inquiry and often suggests new lines of investigation. In the past, new technologies were based on accumulated practical knowledge, but today they are more often based on a scientific understanding of the principles that underlie how things behave. Mathematics is itself a science, but it also provides the chief language of the natural sciences and a powerful analytical tool widely used in both science and technology.
- Science, mathematics, and technology have roots going far back into history and into every part of the world. Just as all peoples have been inventive, shaping tools and developing techniques for modify-

ing their environment, so too they have been curious about nature and how it works. Although modern science—which is truly international—is only a few centuries old, aspects of it (especially in mathematics and astronomy), can be traced back to the early Egyptian, Greek, Chinese, and Arabic cultures.

• Science, mathematics, and technology are expressions of both human ingenuity and human limitations with intellectual, practical, emotional, aesthetic, and ethical dimensions. Progress in these fields results from the cumulative efforts of human beings with diverse interests, talents, and personalities, although social barriers have led to the underrepresentation of women and minorities.

• The various natural and social sciences differ from each other somewhat in subject matter and technique, yet they share certain values, philosophical views about knowledge, and ways of learning about the world. All of the sciences presume that the things and events in the universe occur in consistent patterns that are comprehensible through careful and systematic study. Although they all aim at producing verifiable knowledge, none of them claims to produce knowledge that is absolutely true and beyond change.

• The subject matter investigated and techniques used within the various sciences change with time and the development of new instruments, and the boundaries of the scientific disciplines are constantly shifting. Even so, the general attributes of scientific inquiry persist. Descriptive, experimental, and historical approaches are used, depending on the phenomena being studied and the tools at hand. However, the approaches are all alike in their demand for evidence, their use of testable hypotheses and logical reasoning, their search for explanatory and predictive theories, and their efforts to identify and avoid bias.

• Mathematics is the science of abstract patterns and relationships. As a theoretical discipline, it explores the possible relationships among abstractions without concern for whether they have counterparts in the real world. It often turns out, however, that discoveries in pure mathematics have surprising and altogether unanticipated practical value. As an applied science, mathematics deals with problems that originate in the natural and social sciences and in the everyday world of experience. In trying to solve such problems, it sometimes happens that fundamental mathematical discoveries are made.

• Whether theoretical or applied, mathematics is a creative process rather than one of using memorized rules to calculate answers. Mathematical processes include representing some aspects of things abstractly, manipulating the abstractions logically to find new relationships between them, and seeing whether the new relationships say something useful about the original things. The things studied in this way may be objects, collections, events, processes, ideas, numbers, or other mathematical abstractions.

• In the broadest sense, technology extends our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; to reach farther with our hands, voices, senses, and minds. Engineering is a process of designing and building technological systems to achieve such changes. Engineers must take into account physical, economic, political, social, ecologi-

cal, aesthetic, and ethical considerations, and make trade-offs among them.

- Technological and social systems strongly interact with each other. Social and economic forces determine which technologies will be undertaken, paid attention to, invested in, and used; technology, in turn, has always had an enormous impact on the nature of human society. Some of the social effects of technological change—benefits, costs, risks—can be anticipated, and some cannot.

Scientific Views of the World

Knowledge of science, mathematics, and technology is valuable for everyone because it makes the world more comprehensible and more interesting. *Science for All Americans* does not advocate, however, that all students need to gain detailed knowledge of the scientific disciplines as such. Instead, the report recommends that students develop a set of cogent views of the world as illuminated by the concepts and principles of science. Such views include the following:

- The structure and evolution of the universe, with emphasis on the similarity of materials and forces found everywhere in it, the universe's response to a few general principles (such as universal gravitation and the conservation of energy), and ways in which the universe is investigated.

- The general features of the planet earth, including its location, motion, origin, and resources; the dynamics by which its surface is shaped and reshaped; the effect of living organisms on its surface and atmosphere; and how its landforms, oceans and rivers, climate, and resources have influenced where and how people live and how human history has unfolded.

- The basic concepts related to matter, energy, force and motion, with emphasis on their use in models to explain a vast and diverse array of natural phenomena from the birth of stars to the behavior of cells.

- The living environment, emphasizing the rich diversity of the earth's organisms and the surprising similarity in the structure and functions of their cells; the dependence of species on each other and on the physical environment; and the flow of matter and energy through the cycles of life.

- Biological evolution as a concept based on extensive geological and molecular evidence, as an explanation for the diversity and similarity of life forms, and as a central organizing principle for all of biology.

- The human organism as a biological, social, and technological species—including its similarities to other organisms, its unique capacity for learning, and the strong biological similarity among all humans in contrast to the large cultural differences among groups of them.

- The human life cycle through all stages of development and maturation, emphasizing the factors that contribute to birth of a healthy child, to the fullest development of human potential, and to improved life expectancy.

- The basic structure and functioning of the human body, seen as a complex system of cells and organs that serve the fundamental functions of deriving energy from food, protection against injury, internal coordination, and reproduction.

- Physical and mental health as they involve the interaction of biological, physiological, psychological, social, economic, cultural, and environmental factors, including the effects of food, exercise, drugs, and air and water quality.

- Medical technologies, including mechanical, chemical, electronic, biological, and genetic materials and techniques; their use in enhancing the functioning of the human body; their role in the detection, diagnosis, monitoring, and treatment of disease; and the ethical and economic issues raised by their use.

- Features of human social dynamics, including the consequences of the cultural setting into which a person is born, the nature and effects of class distinctions, the variations among societies in what is considered appropriate behavior, the social effects of group affiliation, and the role of technology in shaping social behavior.

- Social change and conflict, with emphasis on factors that stimulate or retard change, the significance of social trade-offs, causes of conflict, mechanisms for resolving conflict among groups and individuals, the role of governments in directing and moderating change, and the effects of the growing interdependence of world social and economic systems.

- Forms of political and economic organization, emphasizing the intertwining of political and economic viewpoints, the ways in which theoretical political and economic systems differ from each other, and the frequent mixing of capitalistic and socialistic systems in practice.

- The human population, including its size, density, and distribution, the technological factors that have led to its rapid increase and dominance, its impact on other species and the environment, and its future in relation to resources and their use.

- The nature of technologies, including agriculture, with emphasis on both the agricultural revolution in ancient times and the effects on twentieth-century agricultural productivity of the use of biological and chemical technologies; the acquisition, processing, and use of materials and energy, with particular attention to both the Industrial Revolution and the current revolution in manufacturing based on the use of computers; and information processing and communications, with emphasis on the impact of computers and electronic communications on contemporary society.

- The mathematics of symbols and symbolic relationships, emphasizing the kinds, properties, and uses of numbers and shapes; graphic and algebraic ways of expressing relationships among things; and coordinate systems as a means of relating numbers to geometry and geography.

- Probability, including the kinds of uncertainty that limit knowledge, methods of estimating and expressing probabilities, and the use of such methods in predicting results when large numbers are involved.

• Data analysis, with an emphasis on numerical and graphic ways of summarizing data, the nature and limitations of correlations, and the problem of sampling in data collection.

• Reasoning, including the nature and limitations of deductive logic, the uses and dangers of generalizing from a limited number of experiences, and reasoning by analogy.

Perspectives on Science

Scientific literacy also includes seeing the scientific endeavor in the light of cultural and intellectual history and being familiar with some powerful ideas that cut across the landscape of science, mathematics, and technology. To that end, the national council recommends that all students develop the following perspectives on science:

• An awareness that scientific views of the world result both from a combination of evolutionary changes, consisting of many small discoveries accumulating over long periods of time, and from revolutionary changes, consisting of the rapid reorganization of ways of thinking about the world.

• Familiarity with some of the episodes in the history of science and technology that are of surpassing significance for our cultural heritage. Such milestones in the development of Western thought and action include Galileo's role in changing our perception of our place in the universe; Newton's demonstration that the same laws apply to motion in the heavens and on earth; Darwin's observations of the variety and relatedness of life forms that led to his postulating a mechanism for how they came about; Lyell's documentation in layers of rock of the great age of the earth; and Pasteur's identification of infectious disease with tiny organisms that could be seen only with a microscope.

• An understanding of a few thematic ideas that have proven to be especially useful in thinking about how things work. These include the idea of systems as a unified whole in which each part is understandable only in relation to the other parts; of models as physical devices, drawings, equations, computer programs, or mental images that suggest how things work or might work; of stability and change in systems; and of the effects of scale on the behavior of objects and systems.

Scientific Habits of Mind

Throughout history, people have concerned themselves with the transmission of habits of mind—shared values, attitudes, and ways of thinking—from one generation to the next. Given the great and increasing impact of science and technology on every facet of contemporary life, part of scientific literacy consists of possessing certain scientific values, attitudes, and patterns of thought. Accordingly, the national council recommends that elementary and secondary education be modified as necessary to ensure that all students emerge with the following:

• The internalization of some of the values inherent in the practice of science, mathematics, and technology, especially respect for the

use of evidence and logical reasoning in making arguments; honesty, curiosity, and openness to new ideas; and skepticism in evaluating claims and arguments.

- Informed, balanced beliefs about the social benefits of the scientific endeavor—beliefs based on the ways in which people use knowledge and technologies and also on the continuing need to develop new knowledge and technologies.

- A positive attitude toward being able to understand science and mathematics, deal with quantitative matters, think critically, measure accurately, and use ordinary tools and instruments (including calculators and computers).

- Computational skills, including the ability to make certain mental calculations rapidly and accurately; to perform calculations using paper and pencil and electronic calculators; and to estimate approximate answers when appropriate and to check on the reasonableness of other computations.

- Manipulation and observation skills, with emphasis on the correct use of measuring instruments; the ability to use a computer for storing and retrieving information; and the use of ordinary hand tools.

- Communication skills, including the ability to express basic ideas, instructions, and information clearly both orally and in writing, to organize information in tables and simple graphs, and to draw rough diagrams. Communicating effectively also includes the ability to read and comprehend science and technology news as presented in the popular print and broadcast media, as well as general reading skills.

- Critical-response skills that prepare people to carefully judge the assertions—especially those that invoke the mantle of science—made by advertisers, public figures, organizations, and the entertainment and news media, and to subject their own claims to the same kind of scrutiny so as to become less bound by prejudice and rationalization.

BRIDGES TO THE FUTURE

Four major steps are required to make significant headway in realizing the goals expressed in *Science for All Americans*: (1) develop new curriculum models; (2) improve the teaching of science, mathematics, and technology; (3) develop a realistic understanding of what it will take to achieve significant and lasting reform nationally; and (4) initiate collaborative action on many fronts. These steps must reflect the following considerations:

- The school curricula—from kindergarten through twelfth grade—used in today's schools were not designed to achieve the broad goals outlined in this report. To ensure the scientific literacy of all students, the curricula must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid disciplinary boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that influences—and is influenced by—human thought and action; and to foster scientific ways of thinking.

• The effective teaching of science, mathematics, and technology (or any other body of knowledge and skills) must be based on learning principles that derive from systematic research and from well-tested craft experience. Moreover, teaching related to scientific literacy needs to be consistent with the spirit and character of scientific inquiry and with scientific values. This includes starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; providing students with hands-on experience with mechanical, electronic, and optical tools; placing a premium on students' curiosity and creativity; and frequently using a student team approach to learning.

• Educational reform must be comprehensive, focusing on the learning needs of all children, covering all grades and subjects, and dealing with all components and aspects of the educational system. Patching up this or that part of the system will accomplish little. Reform on a national scale will necessarily take a long time, given the size and complexity of the U.S. educational system and the decentralization of authority and resources. It will also require that positive conditions for change be established and that public support for reform be sustained for a decade or longer.

• Finally, to have any hope of success, reform must be collaborative and involve administrators, university faculty members, and community, business, labor and political leaders, as well as teachers, parents, and students themselves. To that end, *Science for All Americans* concludes with an agenda for action that suggests steps that individuals, institutions, organizations, and government agencies can take to work together toward reform. For its part, Project 2061 will continue to do what it can to keep scientific literacy and educational reform on the agenda of educators, scientists, policymakers, and the public.

There are no valid reasons—intellectual, social, or economic—why the United States cannot transform its schools to make it possible for all students to achieve scientific literacy. It is a matter of national commitment, determination, and a willingness to work together toward common goals. *Science for All Americans* is intended to help in clarifying those goals.

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NOTICE

Six reports have been written as part of the first phase of Project 2061, a long-term, multiphase undertaking of the American Association for the Advancement of Science designed to help reform science, mathematics, and technology education in the United States.

These reports consist of an overview report and five panel reports.

The overview report is *Science for All Americans,* written by the AAAS Project 2061 staff in consultation with the National Council on Science and Technology Education.

The titles of the panel reports are as follows:

- *Biological and Health Sciences: Report of the Project 2061 Phase I Biological and Health Sciences Panel,* by Mary Clark
- *Mathematics: Report of the Project 2061 Phase I Mathematics Panel,* by David Blackwell and Leon Henkin
- *Physical and Information Sciences and Engineering: Report of the Project 2061 Phase I Physical and Information Sciences and Engineering Panel,* by George Bugliarello
- *Social and Behavioral Sciences: Report of the Project 2061 Phase I Social and Behavioral Sciences Panel,* by Mortimer Appley and Winifred B. Maher
- *Technology: Report of the Project 2061 Phase I Technology Panel,* by James R. Johnson

For information on ordering all six reports, please contact Project 2061, the American Association for the Advancement of Science, 1333 H Street NW, Washington, D.C. 20005.